TEMPERATURES FATAL TO LARVÆ OF THE RED-HEADED ASH BORER AS APPLICABLE TO COMMERCIAL KILN DRYING

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The demand for seasoned ash stock during the past few years necessitated the extensive use of kiln-dried material. The attention of the Bureau of Entomology was called to several cases where manufacturers, using such material in aircraft construction, reported continued injury by the red-headed ash borer (*Neoclytus erythrocephalus* Fab.) after the wood was kiln dried. As practically no information was available as to what temperatures are fatal to these wood-boring insects, a co-operative project with the Forest Products Laboratory of the Forest Service was suggested by the Branch of Forest Insects of the Bureau of Entomology to ascertain the fatal temperatures and determine if the temperatures in the commercial kiln processes recommended by the Forest Products Laboratory are sufficient to destroy the borers.

The purpose of these experiments and the entomological features were outlined by the Branch of Forest Insects which also furnished the material. The methods of conducting the experiments were outlined by the Forest Products Laboratory in accordance with the laboratory facilities and commercial practices in kiln drying.

Subjecting wood to dry kiln temperatures for the sole purpose of destroying wood-boring insects is, of course, only necessary in cases where more practical methods of preventing the injury have been overlooked or can not be applied under existing circumstances. In these cases considerable injury is already under way which should have been avoided and kiln processes will, therefore, only arrest the damage and prevent further injury by the borers. However, practically no damage from insect attack need be expected if the lumber is kiln dried shortly after it has been felled.

The seasonal history and methods of preventing losses by this insect, as well as another insect, "the banded ash borer" (*Neoclytus capræa* Say), causing similar injury, have been discussed in publications of the

Bureau of Entomology. These wood-boring grubs develop from eggs laid by beetles in crevices of the bark. The banded ash borer flies in the early spring, in the extreme South, from the first part of March to the first part of April, while in the Northern States it flies from the middle of April through May. In the South the first flight of the red-headed ash borer coincides with that of the banded ash borer; however, the red-headed borer continues to appear all summer until the middle of October, while in the North it appears only during June. In those States between the northern and southern limits of distribution the dates of flight are intermediate. These beetles will lay eggs only on logs which are not seasoned, i.e., the inner bark must be still sappy; also the bark must be present. After the eggs hatch the larvæ bore beneath the bark from 4 to 6 weeks before entering the wood.

To avoid the injury by these borers it is therefore essential that the logs be removed promptly from the woods during the flight period of these beetles or not later than 4 to 6 weeks after the earliest dates of flight. They should be promptly sawed or the bark removed before storage, or else they should be placed in water. Four months' submergence in water makes the wood unattractive to the borers and will prevent future attack.

Material.—The material used in these experiments consisted of approximately 20 pieces of ash, 3 feet long, cut from young trees from 3 to 8 inches in diameter. It was cut in April, 1920, and held at the Bureau's Eastern Field Station, East Falls Church, Virginia, where it was attacked in June by the borers. It was shipped in September to the Forest Products Laboratory.

Methods of Sawing.—Inasmuch as this borer confines its activities to the sapwood, it was essential that the sapwood be unmolested as far as possible. Therefore, the 3-foot sections of the trees were merely quartered or halved instead of being sawed into boards of a given thickness.

Condition of Larvæ.—The majority of the larvæ were full grown in their pupal cells in the wood, while a smaller percentage were still feeding in the wood. The treatments were observed on both stages of larvæ, but no noticeable differences in results were observed.

Methods of Procedure.—This study was conducted with a view of determining not only the effect of temperature but also that of relative humidity on the borer. In order that these factors might be isolated, three types of experiments were made.

One set of experiments consisted of treating the infested wood in a kiln held at different temperatures and for various periods. The larvæ were then chopped out and their condition noted. In the other two groups of experiments, the naked larvæ were exposed directly to the different temperatures for definite periods. In one case the larvæ were placed in water of determined and regulated temperatures, and in the other the larvæ were subjected to the dry heat of an electric oven.

In each of these groups of experiments, the condition of the larvæ was noted at the time the treatment was concluded. They were then placed in small glass vials, corked with cotton and held until the larvæ turned dark, due to death, or until activity was noted. Consequently, in some cases it was clearly evident that the larvæ were dead a few minutes after removal from the wood while in other experiments or on other specimens 48 hours were required to determine with certainty the ultimate effect the treatment had on the larvæ.

In the kiln experiments the temperatures were thermostatically controlled and were recorded by a Bristol recording thermometer. These temperatures were also checked by maximum and minimum thermometers. Previous experiments have shown that the temperature within a piece of wood ultimately reaches approximately the dew point of the surrounding air. Therefore, the relative humidity was held at 100 per cent so that the temperature in the wood might be the same as that of the air surrounding the wood. It has also been determined by previous experiments that heat moves through wood slowly—1-inch stock coming to a uniform temperature in about an hour. In view of the fact that the majority of the larvæ were confined to the outer 1 inch of the specimens treated, it was concluded that an hour's treatment at a certain temperature merely brought the wood surrounding the larvæ up to the kiln temperature.

Kiln runs were made at different temperatures and periods of time starting at 160° F. for 1 hour and lowering to 110° F. for 70 hours. In all tests above 128° F. the borers were killed in the experimental runs in periods varying from 1 to 2 hours. Four hours at 120° F. and 16 hours at 116° F. killed only about 50 per cent of the larvæ, while 19 hours at 120° F. killed all the larvæ. One hundred per cent mortality was also secured in 45 hours at 116° F. and in 70 hours at 110° F.

In the water experiments the larvæ were first chopped out of the wood and, if alive and active, were then submerged and held at definite known temperatures for various periods. Temperature and time periods varying from 1 minute at 117° F. to 60 minutes at 125° F. were used. Ten minutes' exposure at 125° F. killed only 50 per cent of the larvæ, while 1 hour killed 75 per cent. Thirty minutes at 120° F. also killed 75 per cent, while 2½ hours at the same temperature killed 100 per cent. All the foregoing temperatures caused cessation of activities within 2 minutes.

In the dry-air experiments the naked larvæ were held at a desired temperature for a definite period. An electrically heated oven was used for these tests and its temperature was determined by an enclosed mercury thermometer which could be read from the outside. Temperatures from 116° to 125° F. and time exposures from 2 minutes to 1 hour were used. Ten and one-half minutes' exposure at 120° F. resulted in death, as well as 122° F. for 5 minutes and 125° F. for 2 minutes. On the other hand, 120° F. exposure for 2, 3, and 4 minutes did not kill the larvæ; nor did 118° F. for 16 minutes. This last temperature (118° F. for 16 minutes) did not cause cessation of activities. All temperatures of 120° F. or above caused cessation of activities after 2 minutes' exposure.

CONCLUSIONS

The outstanding deductions from this study were that the larvæ of the red-headed ash borer are killed in any kiln process which can be considered practical for the seasoning of ash, regardless of the thickness. Even temperatures as mild as those used in Schedule 2, Specification 20,500 A, Bureau of Aircraft Production, which range from 105° to 135° F., are fatal to them. Subjecting infested material to a temperature of 116° F. for 45 hours resulted in 100 per cent death of the larvæ. Temperatures of about 125° to 130° F. will kill the larvæ within an hour after the wood becomes heated through.

Dry heat is fatal to the larvæ at a lower temperature than hot water for the same period.

Water at 125° F. for an hour was fatal to only 75 per cent of the larvæ treated, while dry air at 125° F. resulted in 100 per cent death in 2 minutes. The time required to produce 100 per cent death in dry air at 120° F. was 10½ minutes, while the same effect was produced in water only after 2½ hours. These time limits are not to be

considered absolute limits, but merely to show in a general way that dry air is much more effective than water in producing the death of the larvæ at lower temperatures.

In the dry-air experiments several larvæ of *Xylotrechus colonus* Fab. from hickory were used and the effects were similar to those produced on *Neoclytus erythrocephalus*. Although it is hardly likely that these same temperatures will be equally fatal to other insects such as those native to the Southern States, it is probably safe to assume that if commercial kiln schedules above Schedule 2 are used on other woods, other species of borers that may be in the wood will be killed.